to define margins to account for these residual uncertainties. By shortening treatment time e.g. by the use of VMAT, we expect the intra-fraction cervix-uterus motion to decrease.

OC-0547

Reproducible tumour position in voluntary visually guided inspiration breath hold lung cancer IGRT

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Purpose/Objective: Treatment-related toxicity for non-small cell lung cancer (NSCLC) patients can potentially be reduced by treating in deep inspiration breath hold (DIBH) due to increased lung volume. We investigated the reproducibility of tumour and lymph node position throughout a course of image guided radiotherapy (IGRT).

Materials and Methods: 17 patients were included prospectively. An optical marker based system with visual guidance was used for respiratory monitoring, enabling comfortable voluntary DIBHs. During a coaching session a gating window of 2-3 mm was adjusted individually to each patient's performance.

Besides imaging for radiotherapy (RT) planning, all patients had three additional imaging sessions at treatment fractions 2, 16 and 31. Each session included three consecutive DIBH CTs and one DIBH CBCT, requiring three additional DIBHs. All patients were treated in free breathing.

The reproducibility of DIBH was evaluated as intra- and inter-fractional variations in DIBH lung volume, intra-fractional uncertainty in tumour position and intra-fractional differential motion between the primary tumour and the mediastinal lymph nodes (using carina as an image registration surrogate). When evaluating intra-fractional uncertainty, the second and third daily DIBH CTs were rigidly registered on the first one, matched either on the tumour or the carina. The intra- and inter-observer uncertainty of the manual registration process was evaluated as well.

Potential impact of DIBH on the CTV-PTV margins was investigated.

Results: Lung volume increased in DIBH by 64% (median; range 35-108%; $p < 0.001$; paired t-test) compared to free breathing. Variations in lung volume while the patient was in DIBH were small, with intra-fractional median 1.1% (range 0.1-5.6%) and inter-fractional median 2.1% (0.3-4.6%). There was no intra-fractional trend in lung volume changes, but inter-fractionally there was a slight trend towards increased lung volume on day 31 ($p<0.004$), probably due to tumour shrinkage in some of the patients.

Intra- and inter-observer uncertainties in tumour and carina image registration were < 0.6 mm.

Intra-fractional uncertainty in 3D tumour position was 1.7 ± 1.4 mm (mean ± SD) and below 2 mm for 70% of cases. No trend was observed throughout the RT course. Intra-fractional differential motion between the primary tumour and the mediastinal lymph nodes was 0.0 ± 1.1 mm, indicating good geometrical agreement.

DIBH facilitated a minor margin reduction compared to RT in free breathing, by 1-3 mm, depending on extent of tumour motion in free breathing.

More details are presented in the table.

Intra-fractional uncertainty in tumour position:

Mean ± SD	X [mm] - LR	Y[mm] - AP	Z [mm] - CC	3D [mm]
Day 2	0.2 ± 1.0	-0.4 ± 1.2	0.3 ± 1.3	1.6 ± 1.3
Day 16	0.1 ± 1.1	-0.6 ± 1.6	0.7 ± 1.4	2.0 ± 1.6
Day 31	-0.2 ± 1.0	-0.6 ± 1.5	0.7 ± 1.2	1.6 ± 1.3
All	0.1 ± 0.9	-0.5 ± 1.3	0.5 ± 1.3	1.7 ± 1.4

Intra-fractional differential motion between the primary tumour and the mediastinal lymph nodes

Mean ± SD	X [mm] - LR	Y[mm] - AP	Z [mm] - CC	3D [mm]
Obs 1 first matches	0.0 ± 0.8	0.3 ± 1.1	0.1 ± 1.5	0.0 ± 1.1

Intra-observer uncertainty in tumour match

1 SD	X [mm] - LR	Y[mm] - AP	Z [mm] - CC	3D [mm]
Obs 1	0.6	0.5	0.6	0.6
Obs 2	0.3	0.4	0.3	0.4

Inter-observer uncertainty in tumour match

1 SD	X [mm] - LR	Y[mm] - AP	Z [mm] - CC	3D [mm]
Obs 1 & 2	0.5	0.5	0.6	0.5

Intra-observer uncertainty in carina match

1 SD	X [mm] - LR	Y[mm] - AP	Z [mm] - CC	3D [mm]
Obs 1	0.2	0.4	0.5	0.4

3D tumour position change

	Exceeding 5 mm	Exceeding 3 mm	Exceeding 2 mm
# of CT sets	3/78 (4%)	11/78 (14%)	23/78 (29%)

CTV-PTV margins

		X [mm] - LR	Y[mm] - AP	Z [mm] - CC
DIBH		4	6	5
Free breathing*	tumour motion = 0-5 mm	5	6	6
Free breathing*	tumour motion = 10 mm	6	7	7
Free breathing*	tumour motion = 15 mm	7	8	8

*Based on uncertainties measured at our institution, and used in the clinic.

Conclusions: DIBH is a feasible approach for locally advanced NSCLC. The intra-fractional reproducibility of the tumour position remained high during the whole RT course, provided daily image guidance with tumour match is applied. Additional benefit of DIBH was absence of differential motion between the primary tumour and the mediastinal lymph nodes.

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A comprehensive evaluation of the potential of motion mitigation using re-scanning for the Varian ProBeam system

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Purpose/Objective: To systematically evaluate the effectiveness of re-scanning for the Varian ProBeam PBS proton therapy system in the context of liver tumour treatments

Materials and Methods: 3 deformable motions (mean amplitude of 8/15/20mm, corresponding to Motion A/B/C in figure 1) were extracted from a 4DMRI library (Siebenthal et al 2007, Phys. Med. Biol. 52; Boye et al 2013, Med. Phys. 40) and respectively applied to 3 different liver patient geometries with varying tumour volumes (100/200/400ccm). Reference 3D plans were first calculated to patient specific ITV's ($2Gy_{RBE}$) using spot spacing of 4/8mm for both 1- and 3-field plans. 4D dose calculations were then performed for both regular and irregular motions, each with 4 different starting phases. For each scenario, 1-19 times adaptive-scaled, layered and volumetric rescanning were simulated using the beam profiles, scanning dynamics and beam currents of the Varian ProBeam system. In addition, 4 energy switching times (700/500/200/100ms) were modelled. All 4D dose distributions were assessed by means of the D5-D95 metric in the CTV.

Results: In total, more than 100 thousand 4D calculations have been performed, covering 10 different patient, motion and dose delivery variables. Regardless of patient geometry and motion regularity, the 3-field plans can achieve D5-D95 values within 6.5% of the static values without any re-